B.S.P.S CONF.

PROF PAUL TELLER
UNIV OF ILLINOIS
AT CHIC. CIRCLE

RELATIONAL HOLISM AND QUANTUM MECHANICS[1]

1. Local and Global Physicalism

A physicalist takes the facts about a thing or things to be exhausted by the physical facts. Even granting a distinction between physical and other facts, one may ask what this claim means. Supervenience provides an attractive answer to this question, attractive because the answer is consistent with the absence of explicit reductions or definitions of the non-physical in terms of the physical.[2] The physicalist can say that all the facts supervene on the physical facts, meaning by this that whenever two real or counterfactual things or cases agree in all their physical characteristics, they agree in all their other characteristics also. To avoid trivialisation, we must take the physical characteristics of a thing or case to be its non-relational (or intrinsic) physical characteristics. We have no sharp analysis of relational vs. non-relational characteristics or properties, so we will have to make do with our rouch and ready preanalytic understanding of this distinction. Intuitively, when we say that two things or cases which agree in all their physical characteristics also agree in other respects, we must understand the physical characteristics of an object as the facts about the object's internal physical structure, as the physical properties the object has independently of the state of other objects and we must likewise take the "other respects" - the "extra physical facts" - in the same non-relational sense.

So far I have spoken vaguely of "things" or "cases". One may opt here for either of two more clearly specified alternatives. On the first, one may explain physicalism as the thesis that whenever two re-identifiable, narrowly localisable individuals - things in the narrow sense - have the same intrinsic physical properties, then they have the same intrinsic non-physical properties too. I will call this local superveniance of the non-physical on the physical or local physicalism for short. I suspect that local physicalism is what expresses our untutored physicalist intuitions. I intend local physicalism to suggest a contrast (a contrast which is not sharp) with the case in which supervenience is applied not to narrowly conceived individuals but to broader contexts, situations, or settings.

Local physicalism faces an immediate problem, for it is not clear how it can deal with relational properties. Clearly, two individuals can be exact physical duplicates or replicas and yet can differ as to properties such as being the largest planet in a planetary system or being a Cadillac owner. One can try to get supervenience of general relational properties on the physical by applying the idea of supervenience to all the intrinsic and relational physical properties holding of or among all the things entering into the relevant supervening relations. But it would be messy to carry out this idea systematically

because often one must deal with a non-specific number of relevant individuals entering into the relations, for example when the individuals are covered by an existential quantifier. So some authors appeal to the simple expedient of covering everything at once. They say that given two possible ways the whole world might be, if those two ways agree in all physical respects, (including physical relations) then the two ways agree in all other respects as well. I will call this global supervenience of the non-physical on the physical, or global physicalism for short. Global physicalism automatically takes care of the problem of relational properties.

2. Relational Holism

I suspect that global physicalism does not express what most of us pre-analytically understand by physicalism. Our pre-analytic idea is that the world is fixed by the physical facts pertaining, one by one, to individual objects. We imagine that relational properties then arise from these individual physical facts. In particular, many relational properties are supposed to come about as a result of individuals causally interacting with each other in virtue of their intrinsic physical properties. But fix the intrinsic physical properties, of all individuals and everything has been fixed.. By way of contrast, if only global physicalism is true we do not really have the physicalism pictured by the 18th century metaphor of the world as a great clock.

Given the ubiquity of relational properties we can have local physicalism only if relational properties supervene on the non-relational ones. Presumedly the important key is to show that physical relational properties supervene on the physical non-relational properties. Indeed, examples encourage optimism for this method of getting global physicalism to collapse back down to local physicalism. The relation of x is longer than y supervenes on the non-relational properties of x and y, specifically on their intrinsic length. The same kind of thing goes for is heavier than, has the same charge as, and other physical relations. The hope is that once all the non-relational physical properties of objects are set, then so are all the relational physical properties, and so then all the non-physical properties as well.

The present paper suggests that this hope will be frustrated. I will appeal to a widespread class of plausible cases (well known in the context of other problems) in which collections of objects have physical relational properties which do not supervene on the intrinsic physical properties of the parts. If we are disappointed as local physicalists the problem offers us a kind of consolation prize, for the very statement of the problem provides help with a previously intractible issue for analytic philosophers. Holism has always seemed incoherent, for it seems to say that two distinct things can somehow be entangled or intermeshed so that they are not two distinct things afterall. Yet

apparent unintelligibility does not prevent holism from recurring, not only in the work of philosophers of East and West, but also in what quantum mechanics seems to many of us to be saying about the world. The statement of local physicalism's failure suggests a reading which we can give to holism which analytic philosophers ought to find relatively clear. By relational holism I will mean the claim that objects which in at least some circumstance we can identify as separate individuals can have ineliminably relational properties, that is relational properties which do not supervene on the non-relational properties of the distinct individuals. The failure of local physicalism leaves us with a kind of holism, but at least it is a holism we can understand.

3. Relational Properties in Classical Physics: Discussion of Some Examples.

I don't think that classical physics provides any really clean examples of ineliminably relational properties. But I want to touch on two examples because I feel they are needed for a systematic view of the topic and because I hope others will think about some of the questions which come up along the way and which have me very puzzled.

Consider the case of classical mechanic's point particles under the influence of gravitational forces. In some sense, what is true about one particle depends on all the rest, since the acceleration, or force, experienced by one particle depends on where the others are. We customarily gloss this situation without appealing to ineliminably relational properties. We say that each particle has its full complement of properties which we unreflectively take to be non-relational - properties such as position, mass, velocity, and acceleration - and we say that changes in these properties are caused by the circumstance of other particles at other places having similar properties. While the causal connection itself may constitute a relation, repetition of the same mass, position, velocity, etc. in the same array would result in the same causal connections. So the causal connections would not seem to be ineliminably relational. This gloss has a price, of course. It involves action at a distance, which philosophers and physicists since Newton have found mysterious and even nonsensical. (I want to put aside for the moment the other obvious problem with this gloss, the relationality of position and velocity.)

Classical mechanics gives us an alternative to action at a distance. Objects have potential energy, and one can say that it is local changes in potential energy, not distant causes, which produce change in velocity. But potential energy, properly understood, is a relational property. Instead of saying that each of two particles causes the other to have a potential energy,

mysteriously, instantaneously, and at a distance, we should say that the potential energy is a relational property that holds between the two particles. We know that in general properties which we appear to attribute non-relationally to individuals often really are relational properties holding between several individuals, as when we speak of my being married as a property I have, instead of as a relation which holds between me and my wife. Similarly, talk in classical mechanics about the potential energy of a particle is really implicit talk about the mutual potential energy which holds between particles.

It will help comparisons which follow if we can give more detail now on how appeal to potential energy works. Technically, a differential equation relates rate of change of potential energy in space to rate of change of velocity in time. By recasting this statement informally, we can see how a differential equation can give an account of change without appealing to action at a distance. Think of time and space broken up into very small cells. It is the fact that the potential energy of a particle in a spatial cell differs from the potential energy in an immediately neighbouring cell that is responsible for a difference in velocity between the present and the next temporal cell. We can take these cells to be arbitarily small, which gives us a sense in which no action at a distance has been involved. Finally, although we customarily phrase such an explanation in terms of the potential energy of a particle in a cell, we must keep in mind that these potential energies are really relational. We are concerned here with potential energies relative to distant bodies, that is with the potential energy relation which holds between the particle in question and the other particles in the world.

In sum, classical mechanics can present the springs of change in two prima facie very different ways: in terms of action at a distance or in terms of the relational property of potential energy. One wonders whether, or in what way these two accounts are simply two different expressions of the same facts.

But are the relational properties of potential energy ineliminably relational? In classical physics, mass and (relative) position determine potential energy. So, if the laws of classical physics hold in all possible worlds the potential energy relation supervenes on mass and position. However, if there are possible worlds in which potential energy is a function of other things, the supervenience base for potential energy must be correspondingly enlarged. Position, of course, is really relational, and ineliminably so. So at best the potential energy relation supervenes on ineliminably relational position and on other non-relational properties. Of course, the same can be said of causes acting at a distance. They too, at best supervene on ineliminably relational position and

on other non-relat-onal properties.

We get a surprising contrast with a second example, that of point particles under the influence of electromagnetic forces in relativistic electrodynamics. Electrodynamics develops the field concept nascent in the idea of potential energy, giving fields a much more substantive role; but the relationality drops out. Electromagnetic fields - light is an example - have energy and momentum, and propagate on their own through space-time. It is because the fields themselves propagate that electromagnetism can do without action at a distance and without irreducibly relational properties. Again, a differential equation describes change, this time change in the electromagnetic fields. Differences in the fields in neighbouring spatial cells govern changes in the fields between neighbouring temporal cells, so that changes in the field move, or propagate through space-time rather like ripples on the surface of a pond. Propagating electromagnetic fields then serve as the vehicle by which distanct particles affect each other. A particle at point a can affect the fields present at a. This change then propagates through space-time to b where the change in fields affect a particle at b. Neither action at a distance nor relational properties enter the picture to spoil the idea of the world working as a giant mechanism, understandable in terms of the working of the individual parts. To be sure, we have had to liberalise our notion of "part" to include field quantities at space-time points. But in supporting the conception of local physicalism relativistic electrodynamics counts as more classical than classical mechanics.

relatio[illegible]

relation between field & particle to set particle's [illegible] states?

4. Relational Properties in Quantum Mechanics.[3]

A massive re-entry of ineliminably relational properties provides one mark of the sharply non-classical nature of quantum mechanics. Ineliminable relationality seems to drop entirely away from relativistic electrodynamics, and in classical mechanics it may be limited to the relationality of space. But ineliminably relational properties inundate quantum mechanics if the state function is given any realist, non-instrumentalist interpretation.

To understand how ineliminably relational properties get into quantum mechanics we need to understand superimposed properties. To set ideas I will begin with a graphic statement, warranted only on certain interpretations of the state function. A quantum mechanical system can have certain properties, such as an exact position, x_1, an exact position, x_2, an exact momentum p_1, or an exact momentum, p_2. (To smooth the exposition I pretend that positions and momentum are discrete quantities. This simplification does not affect any points at issue.) Superposition is a way in which properties of one kind, say position, can "combine" to form properties of another kind, such as momentum.

[illegible] we the state of [illegible] momentum p are distinct, require correcting, - but [illegible] I am clearly of the state -ψ- as two property - this is confusing here.

The two exact positions, x_1 and x_2, can combine or 'superimpose" to make a new property, say p_1, which is distinct from both of the original superimposed properties, x_1 and x_2, and indeed from all exact positions.

A more careful statement of superposition also clarifies what superposition involves. Quantum mechanics delivers its information about objects of systems in terms of mathematical descriptions called state vectors or state functions, which are linked to observational results, such as observed positions or moments, in terms of probabilities. A system characterised by a given state function will reveal a given observational characteristic with a probability which the state function specifies by a simple algorithm. In special cases these probabilities will be 1. One state function will give an object a probability of 1 for having exact position x_1, a second state function will give an object a probability of 1 for having position x_2, a third a probability of 1 for p_1, a fourth a probability of 1 for p_2, and so on. These special state functions are called eigenstates (or proper states) for the properties assigned a probability of 1. Here I want to understand eigenstates, and state functions generally, just as mathematical descriptions and stay neutral, for the time being, as to how they should be interpreted.

The idea of superposition enters because state functions can be numerically added, and when we add two state functions together we get a new state function. We use the word "superposition" because a state function can also be seen as a description of an undulatory or wave-like proces. So when we add two state functions together we are doing something just like adding together the description of two wave processes and getting a description of a new wave process, where the new wave process is just the one obtained by superimposing the two wave processes described by the original state functions. The superposition of state functions then applies to properties, such as the "superposition of two exact positions" as follows: If we start with an eigenstate for the position x_1 and a second eigenstate for position x_2 and add them together we get a new state which is an eigenstate for momentum p_1 and which is not an eigenstate for any exact position.

How we should understand this more careful statement of superposition of properties depends on how we should interpret state functions. Let me illustrate with a strong interpretation. Suppose we say that a system has a property if and only if it is in an eigenstate for that property. Suppose we also take state functions, and in particular eigenstates, to be referring expressions, which refer to actual states of the systems to which they apply. In particular we will take eigenstates to refer to the properties specified by the eigenstate, that is, the property which an object has just in case it is in the corresponding

eigenstate. Under these assumptions the careful statement of superposition provides a way of understanding the initial strong statement by giving us a clean connection between eigenstates and their associated properties: To say that momentum p is a superposition of positions x_1 and x_2 is just to say that the eigenstate referring to p_1 is the superposition (the sum) of the eigenstate referring to x_1 and the eigenstate referring to x_2.

However, we are not forced to embrace such a strong interpretation. At the opposite extreme we have an instrumentalist interpretation of the state function which casts the state function as a mere verbal mechanism, an aid in predicting observational results but not a referring or toherwise meaningful expression. On an instrumentalist interpretation we have no reason to think that the world exhibits these surprising properties which are interconnected by superposition. Since ineliminably relational properties enter quantum mechanics as special kinds of superposition, and since instrumentalism takes quantum mechanics to have no superimposed or superimposable properties, ineliminably relational properties are not inevitable in quantum mechanics. But I am very reluctant to settle for instrumentalism. In what follows I will lay instrumentalism aside and restrict attention to what happens in a non-instrumentalist interpretation in which there is some combination of or systematic connection between properties or states of real objects, as described by the formal manipulation of adding state functions.

Even on a non-instrumentalist interpretation, superposition does not yet indicate anything about relational properties. On the strong interpretation I cited as an example, two properties of an object may superimpose. But the new superimposed property is simply another non-relational property of the same object. In order to get relational properties we must look at the superposition of properties of groups of objects taken together. Let's consider two objects, *a* and *b*, and let's consider their properties which I will indicate generically with the letter 'w'. A superscript on 'w' tells us which object is in question and a subscript indicates the specific property. Thus w_1^a indicates the circumstance of *a* having property w_1, w_2^b indicates the circumstance of *b* having property w_2, and so on. I will also use the same expressions to indicate the associated eigenstates. Thus w_1^a indicates the eigenstate in which a has property w_1 with probability 1, etc. Next we consider the properties of each of *a* and *b* when *a* and *b* are taken together. For example $w_1^a a_2^b$ indicates the circumstance of *a* having w_1 and *b* having w_2, and this same expression, $w_1^a w_2^b$ also indicates the compound eigenstate in which *a* is sure to have w_1 and *b* is sure to have w_2. While $w_1^a w_2^b$ might be taken to be a relational property, it is not a candidate for

an ineliminably relational property. Exactly the same goes for the distinct compound property (or eigenstate) $w_2^a w_1^b$. But given these two compound properties quantum mechanics tells us that their superposition, $w_1^a w_2^b + w_2^a w_1^b$, is also a property which the paid, a,b, can have. This property is a relational property which holds between a and b, or of a and b collectively; and except in degenerate cases this property does not reduce to or supervene upon non-relational properties of a and b taken separately. This conclusion follows immediately under the assumption of the strong interpretation, that a system has a property if and only if it is in the corresponding eigenstate. With this assumption the conclusion is an immediate consequence of the fact that (except for degenerate cases) states $w_i^a w_j^b$ and $w_1^a w_2^b + w_2^a w_1^b$ are distinct so that a system in one is never in the other. The conclusion can also be argued without the assumption that if a system has a property then it is in the corresponding eigenstate, but as the argument is somewhat long and technical I will not give it here. Bell + K[illegible]

It is important that in at least some cases the ineliminably relational properties like $w_1^a w_2^b + w_2^a w_1^b$ are independently ascertainable properties of pairs of systems and not just theoretical phantasms of quantum mechanics. The example of Einstein, Podolsky, and Rosen is a superposition of (actually infinitely many) exact positions of a and of b which constitutes an eigenstate of the distance between a and b, and also an eigenstate of the total momentum of a and b, but not of any specific positions or momenta of a or of b. Even if one assumes that quantum mechanics is incomplete and that a and b each have definite positions and moments not predicted or described by quantum mechanics applied to this state, the relational properties of separation and total momentum do not supervene on the postulated non-relational properties of the individuals. Exactly the same kind of thing goes for the example used by Bell. In this case we consider two particles with the non-classical property of spin, and we construct a certain simple superposition of two non-relational spin states of a and of b. In this superposition quantum mechanics does not assign a definite spin to either particle in any direction, and in analogy to the last case, even if one postulates specific spins for particles in the superimposed state the property described by the superposition does not supervene on the postulated individual properties. And again, the superposition characterises an independently identifiable property, having spin zero, of the a-b system as a whole.

Have to say, in talking about alternatives to no h.v. only, take h.v. in addition to ψ [illegible]

if hidden variable theories can't [illegible] claim ψ is [illegible] – the ψ are measures of our ignorance from ensembles or the like, alternative characterisation "superimposed properties" – better [illegible] are in conflict with hidden variable theories

5. Conclusion

Earlier I suggested that ineliminably relational properties provide an intelligible formulation of holism, which I dubbed relational holism. This idea now applies to quantum mechanics. The strange ways in which things seem

interdependent in quantum mechanics has often suggested holism to interpreters, but they have been reluctant or uneasy about embracing the holism because of its obscurity. The suggestion of applying relational holism to this problem gives us a proposal for further clarification and critical examination. Quantum mechanics describes individuals which, often at least, we can distinguish from each other. But these distinguishable individuals can also have ineliminably relational properties. The work to be done includes a closer examination of whether we have a specifiable and acceptable account of distinguishable individuals which is consistent with the claim that such individuals may also have ineliminably relational properties. One worry I have in mind here concerns possible problems with quantum statistics for identical particles. It is possible that these quantum statistics can themselves be clarified by applying the idea of ineliminably relational properties.

Ineliminably relational properties are also important to interpreting quantum mechanics because they play a central role in many of the theories central puzzles. They are the properties that hold between measurement devices and measurement objects which generate the problem of measurement. They are the properties which give rise to the non-classical statistics which violate Bell's inequality. And so on. Seeing that ineliminably relational properties are at the heart of these puzzles does not by itself lead to their resolution. At best this insight will facilitate a partial restatement. But given our state of bewilderment, restatements may be valuable.

Most importantly, ineliminably relational properties give us an improved view of quantum mechanics' break with classical intuitions, or at least an improved view of an important part of this break. I suggested earlier that we understand classical physicalism as the supervenience of all the facts on the non-relational physical facts about physical objects. If we reject instrumentalism quantum mechanics tells us that physicalism can at best come to supervenience on ineliminably relational properties and that the world is a more deeply intermeshed web than we thought. Indeed, according to quantum mechanics the extent of entanglement through ineliminably relational properties is all pervasive. Each and every scattering interaction gives rise to ineliminably relational properties, so that every non-isolated object gets caught up with other objects in the web of the ineliminably relational. One of quantum mechanics' basic puzzles is how these ineliminable relational properties connect with non-relational properties. The step we may need to take to advance our physical theory and our conceptual scheme for the physical world may be to come to terms with ineliminably relational properties and to understand how they give rise to (or come to be seen as) the non-relational properties which have so far formed the basis of our physical world view.

NOTES

1) This research was supported by a National Endowment for the Humanities Fellowship for Independent Study and Research.

2) In this compressed presentation I pass over a huge number of details concerning the multifaceted idea of supervenience. These details have been surveyed in Teller (1984).

3) From one perspective I do little more in this section than restate an idea put forward in a number of places by Allen Stairs, but most fully in his (to appear). Stairs in turn takes an important lead from Shimony (1978, 1980), and one should also mention d'Espagnat as an important source for these ideas (e.g., 1973). I hope that by using the notion of supervenience, and by drawing connections with some more traditional themes I have succeeded in throwing a little........

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